Numerical Simulation of Neck Propagation in Double Network Hydrogel

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Double network (DN) hydrogels have drawn much attention as an innovative material having both high water content and high mechanical strength and toughness. Futhermore, yielding phenomenon was observed in some tough DN gels[1]. For example, on tensile tests of DN gels that made from relatively sparse first networks, narrow zones appear in the sample and grow up with further stretching. During the neck propagation, a plateau region appears in the loading curve. The plateau value of the tensile stress hardly depends on the stretching rate. After the neck propagation, the gel becomes fairly soft, showing an elastic modulus *ca.* 1/10 of the virgin sample, and sustains large elongation, up to an elongation strain of around 20. The observations on the softened gels after the tensile test demonstrate that irreversible structural change takes place inside the gels, although their appearance is almost unchanged.

In this study, we at first employ a nonaffine polymer chains network model[2] to account for such irreversible structural change during the deformation of DN gels. And then, a finite element model of the DN gels under simple tension is constructed. On the other hand, neck propagation is one kind of localized instability and there will be a local transfer of strain energy from one part of the model to neighboring parts. This class of problems has to be solved either dynamically or with the aid of (artificial) damping; for example, by using dashpots. Fortunatly, Abaqus/Standard provides an automatic mechanism for stabilizing unstable quasi-static problems through the automatic addition of volume-proportional damping to the constructed model and the applied damping factors can vary spatially and with time to account for changes over the course of a step, where the damping factor is controlled by the convergence history and the ratio of the energy dissipated by viscous damping to the total strain energy. Furthermore, Abaqus/Standard can reduce the time increment to permit the process to occur without the unstable response causing very large displacements.

The simulation results show that the nonaffine polymer chains network model can be employed to reproduce neck propagation in DN gels very well.

REFERENCES

[1] Gong, J.P., Why are double network hydrogels so tough? *Soft Matter* (2010) **6**: 2583–2590.

[2] Riku, I. and Mimura, K., Study on the change of entangling structure of molecular chains during the tensional and swelling process of elastomeric gel. *Proceedings of the 10th International Conference on Computational Methods* (2019) 391–396.